About *De Motu Cordis*

Commentary by Robert G. Frank Jr.

Binding, Collation, and Provenance

William Harvey
Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus

Frankfurt, 1628

The short and unpretentious work presented here for the first time in digital format is one of a handful of undoubted classics in the history of western scientific thought. *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* is perhaps best rendered into English as "Anatomical Exercise on the Motion of the Heart and Blood in Animals," with "Exercise" having the sense of a formal academic argument. It is universally known to scholars by the abbreviated form of its Latin title, *De Motu Cordis*. Like the books on astronomy by Nicolaus Copernicus in 1543, and on physics by Isaac Newton in 1689, the publication of *De Motu Cordis* in 1628 marked the overthrow of a tradition of scientific explanation that had endured for almost 1500 years, inaugurating within the biological sciences a new mode of explanation based on close observation and direct experimentation. Unlike the two other landmarks, which were written in hundreds of pages of dense and convoluted mathematical argument, the prose of Harvey's masterpiece is tight, concrete, straightforward, and sometimes even personal. The ideas and

conclusions of Copernicus and Newton set great controversies in motion, but the books themselves were only very infrequently reprinted, and not translated from their original Latin until much later. Harvey's small book, by contrast, was reprinted 10 times within three decades of its publication, including the English translation of 1653, which forms the basis of the translation in this Octavo Edition.

Because it is brief, well argued, and relatively non-technical, *De Motu Cordis* is very probably the one and only great classic of western science written before 1800 that is still widely read today: by undergraduates in courses in the history of science, by medical students and practitioners, and by students of the physiological sciences. It is still available in multiple paperback editions, and it has even been transformed into a motion picture, *William Harvey and the Circulation of the Blood* (Royal College of Physicians, 1928 and 1957).

William Harvey wrote his masterpiece in the midst of a successful career as a highly respected London physician, one for which his background had prepared him well. Born in 1578, in historical time a younger contemporary of William Shakespeare (1564-1616), he was raised in comfortable upper middle-class surroundings in the small southeastern English port town of Folkstone. He mastered the requisite Latin skills in an elite boarding school in the nearby cathedral city of Canterbury, and in May 1593, matriculated at Gonville and Caius College, Cambridge. His six and one-half years of study at the university were focused at first on rhetoric, logic, and especially philosophy, while after taking his B.A. in the summer of 1597 he learned a smattering of Aristotelian physics, astronomy, biology, anatomy, and meteorology. His departure from Cambridge in December 1599 seems to have been with the intention of studying medicine, because he appeared soon afterward at the best medical school in Europe, the University of Padua, near Venice in Italy. Two years of further study brought him not only a handsomely inscribed diploma as Doctor of Medicine and Philosophy (1602), but acquaintance with the best anatomical teachers in the world, primarily in the person and works of the Paduan professor, Hieronymous Fabricius ab Acquapendente (1533-1619).

Immediately upon his return to England Harvey passed the examinations (1603-04) that led to his admission as one of the thirty Fellows of the Royal College of Physicians of London, a professional body that had official control over all practice in the booming metropolis of perhaps 225,000 souls. In 1604 he married the daughter of one of the College's leading Fellows and began his upward rise: appointed in 1609 as physician to London's premier hospital, St. Bartholomew's; elected one of the College examiners in 1613; sworn physician to the British monarch, James I (1618) and later to his son Charles I (1625); and – most momentous of all – appointed in 1615 as the College's Lumleian Lecturer in Anatomy and Surgery.

The Lectureship, which paid Harvey a stipend equivalent to that of a university professor, obligated the busy practitioner to lecture at the College for an hour twice each week, and to conduct a biennial public dissection of a cadaver. His notes for these lectures and dissections circa 1616-1619 have survived in the British Library, and they show how Harvey's teaching agenda became the occasion for discovering first a new interpretation of the motion of the heart, and thereafter the circulation of the blood.

Traditional Galenic Explanations

To appreciate Harvey's two discoveries, it is necessary to understand Galenic ideas about the heart, lungs, and blood, as they were taught in the late sixteenth century. Early modern physicians regarded the veins and arteries not as two parts of the same circulatory system, but as two separate, interpenetrating systems, only minimally related to each other. All veins were thought to have their origin in the liver. That organ was believed to attract nutritious matter from the food products in the intestines, and to process that nutriment into venous blood, which was carried by the veins to all parts of the body to nourish them. The reservoirs for this venous blood were the *vena cava*, the right atrium, and the right ventricle of the heart. Venous blood was dark red in color and thicker in consistency, and therefore veins needed only to be thin and flexible to contain it. Arterial blood was seen as very different, being thinner, more active, bright-red in color, carrying heat and vivacity via its inherent "vital spirit." To contain this blood, the arteries themselves were thicker, had recognizable muscle in their walls, and by virtue of this muscle could pulsate, thereby distributing heat and life to all the parts.

The heart, and especially the left ventricle, was seen as the source of all arteries, the origin of heat in the body, and the organ that elaborated the vital spirits. It carried out these functions because of its special relation to the lungs. They brought in air, and the most subtle part of this air, the "pneuma," was carried to the left ventricle. There the pneuma met a penetrating and active portion of venous blood – known as subtle blood – from the right ventricle that had worked its way through postulated "pores" in the interventricular septum. This subtle blood combined with the pneuma and, having been acted upon by the heat and constant motion of the heart, produced vital spirits that could be carried by the arteries throughout the body.

The motion of the heart was perceived to be twofold: a diastole, in which it swelled by an active process and became larger, and a systole, in which it became smaller. At this point, traditional Galenic physiology made a crucial explanatory assumption. Because it was believed that the muscular coat of the arteries was continuous with the muscle-like substance of the heart, it was also assumed that *ventricles and arteries moved in synchrony with each other*. The diastole (or expansion) of the heart corresponded to the diastole of the arteries and hence gave rise to the pulse. The systole (or collapse) of the heart corresponded to the diminution of the arteries. Since it could be observed that the pulse of an artery corresponded with the external "beat" on the wall of the chest, it was further believed that diastole of the heart caused a visible "apex beat."

The ventricles of the heart were seen to be connected to the lungs by two sets of vessels. One ran from the right ventricle to the lungs, carried nutritious blood there, and was called a "vein" because of its connection to the venous part of the heart, because it contained venous blood, and because of its presumed function of nourishing the lungs. Oddly, though, this "vein" had a thick coat like an artery, and hence was called the "artery-like vein," or the "arterial vein." Another set of vessels ran from the left ventricle via the left atrium to the lungs, and because of its origin, and because the pneuma in these vessels linked them to the arterial/vital system, they were

called "arteries." Oddly, they had thin coats much more similar to veins, and hence collectively were called the "vein-like artery," or the "venous artery." Harvey himself used this nomenclature, and it was replaced by the modern usage of "pulmonary artery" and "pulmonary vein" only later as a result of his discovery. Any contemporary reader has to keep the following equivalencies clearly in mind:

Right Ventricle to Lungs = "arterial vein" = pulmonary artery

Lungs to Left Ventricle = "venous artery" = pulmonary vein

There were of course many other subtleties and consequences of the Galenic doctrine of the heart, but the aspects of the theory described here were the main features before Harvey's mind as he sat down to compose the portion of his lectures concerning the heart.

Part-Way to Discovery: The Lumleian Lectures

What made Harvey's treatment of the heart different from all of his predecessors was that he analyzed the problem from two simultaneous, unique approaches: as an Aristotelian biologist and as a vivisectionist. Unlike many of his medical colleagues, Harvey was not overwhelmingly interested in how the *human* heart functioned, but rather in the broader, more Aristotelian question: "How do hearts in general function?" This lead him to dissect, and to introduce into evidence, an astonishingly wide range of animals: from the more common cats, dogs, and pigs to snakes and frogs, shrimp, and flies. He even once dissected an ostrich from the King's menagerie. It is very significant that the title of Harvey's book proposed to discuss the motion of the heart and blood *in animalibus*. Moreover, because he was interested in the *function*, the *action* of the heart, and not merely in the details of its anatomy, Harvey was led to carry out numerous vivisectional experiments in which he opened many different kinds of living animals, observed the beating heart, and tried to puzzle out its movement, even though the heartbeat took place, as he bemoaned, "in the twinkling of an eye."

From these combined approaches to the heart, one comparative and the other experimental, Harvey could present to his London auditors a new picture of the motion of the heart. First, he concluded, the right and left atria (called "auricles" or "little ears") would contract simultaneously, thrusting blood into the ventricles and causing them to expand, and experience diastole. Diastole of the ventricles was not, therefore, an active process, but rather a passive one, caused by being filled with blood from the contracting atria. The ventricles are then roused, they contract forcefully in systole, and thrust out the blood contained within them. When the ventricles contract in active systole, the heart rises and twists, striking the chest wall, and causing the apex beat. Further, when the ventricles, and especially the powerful and muscular left ventricle, eject blood forcefully into the arteries, they expand passively. It was, Harvey said, like blowing into a glove. The diastole of the arteries – that is, the pulse – corresponds therefore to the *systole* of the heart and is the simple hydraulic result of the left ventricle ejecting blood into the arterial tree, not the result of a "pulsific faculty" of active expansion shared with the heart.

Harvey's observations of this chain of events led him to consider more closely the four sets of valves in the heart: 1. between the right atrium and the right ventricle; 2. between

the right ventricle and the "arterial vein" [pulmonary artery]; 3. between the "venous artery" [pulmonary vein] plus left atrium and the left ventricle; 4. between the left ventricle and the aorta, the beginning of the arterial system. All of these valves, he argued, are contrived to allow blood to *move in only one direction* when it is squeezed by a contracting atrium or ventricle. Thus the blood must move: *Vena cava* -> Right Atrium -> Right Ventricle -> "Arterial Vein" -> Lungs -> "Venous Artery" -> Left Ventricle -> Aorta. Hence the blood that goes from the right side to the left side of the heart does not pass through "pores" in the interventricular septum but through the soft texture of the lungs in a pulmonary transit.

None of Harvey's three specific ideas – that ventricular systole causes the apex beat, that active ventricular systole expels blood forcefully to cause the arterial diastole (pulse), that blood flows across the lungs from the right ventricle to the left – was entirely new. Each had been separately suggested (but not proven) by sixteenth-century anatomists with which Harvey was familiar, such as Realdo Colombo and Andrea Cesalpino. But no one had argued for all three, and no one had done so on the basis of the comparative and vivisectional evidence that Harvey had brought to bear on the problem. The attendees of his London lectures were hearing something very new.

The Discovery of Circulation and the Publication of *De Motu Cordis*

We know from Harvey's testimony in his dedicatory letter to John Argent, the President of the Royal College of Physicians, that his research into the action of the heart was presented on "several" occasions, was confirmed by "numerous ocular demonstrations" before the College, and was subjected to the criticism of his colleagues. It was during this period, Harvey says, that he began to contemplate the possible implications of this new view of how the heart moved and how that motion affected the blood.

Harvey described the elements of his analysis in a famous and convoluted passage in Chapter 8 of *De Motu Cordis*. In an attempt to discover, he says, *how much blood* thus passes from the *vena cava*, through the right ventricle and lungs and left ventricle, to the aorta, he carried out more "dissections of living things," especially the functioning arteries. He considered the size and symmetry of the ventricles and great vessels and assumed like a good Aristotelian that Nature does nothing without purpose. He recalled the elegant and carefully contrived valves ("doors") placed in the heart at four points in the flow of blood, and how they seemed to be quite efficient at preventing backflow. Finally, he asked himself this question: If venous blood was always thus being moved through the heart to the arteries in great abundance, how could the "juice" of the ingested food provide enough raw materials for such a great amount of venous blood, and why did the arteries not burst from the excessive inthrust of arterial blood?

Harvey concluded that the blood in the periphery had to pass back again from the arteries into the veins. "I began," Harvey says, "to bethink myself if it might not have a circular motion." Sometime between about 1619 and 1628, he worked out the arguments for the circulation of the blood and wrote them into the small book that was published in the latter year at Frankfurt am Main, a continental center of the learned book trade.

De Motu Cordis falls into two distinct parts pivoting about a single point. In the beginning of the first part, in the "Introduction" or *Proem*, Harvey lays out all the inconsistencies of previous opinions about the heart, lungs, veins, and arteries. Then, in chapters 1 through 7 he leads the reader through all of his conclusions about the sequence of movements in the heart as observed in vivisection. Chapter 8 is the pivotal point where, after recapitulating the evidence, he introduces the possibility of a circular motion. The second part of the book, chapters 9 through 17, attempts to prove, through three key suppositions, that this circular motion does indeed occur.

The first of Harvey's three suppositions is that the quantity of blood transferred across the heart from the *vena cava* to the aorta is too great to come from absorbed foodstuffs. He makes this argument both quantitatively and experimentally. The first argument is by a rough calculation of how much blood is expelled from the ventricles in each stroke, and therefore how much blood must be moved by the heart in a short period, such as an hour. Although this argument has been seen by some later writers as one of the earliest examples of "quantification," its aims are more rhetorical and general than arithmetical and precise. Harvey gives few exact measurements and wants to emphasize that no matter how one minimizes the amount of blood ejected, it *must* in a short period of time greatly exceed the quantity of fluids that could be manufactured from blood. Just as important in proving the transfer across the heart is his series of vivisectional experiments showing the unidirectional flow in chambers and vessels.

His second supposition is that arteries carry into the limbs and periphery too much blood simply to be absorbed there.

He supports this argument with an ingenious series of experiments in which ligatures are tied around a human arm at several levels of compression: very tight to compress both arteries and veins, and moderately tight to occlude the surface veins while allowing blood to flow in the arteries that lie more deeply. These experiments are all the more convincing because the phenomena observed in both kinds of ligatures were well known to practicing physicians, who used them for bloodletting.

His third supposition is that the sole function of the veins is to return the blood from the extremities to the heart. Here again he uses ligature experiments that can easily be duplicated by a physician. Moreover, to support his contention, he reinterprets the discovery made by his teacher Fabricius that veins contain valves. Whereas Fabricius had believed that these valves pointed upward to prevent too much blood from accumulating in the legs and arms, Harvey showed that they pointed both upward and downward but always so as to direct the flow of blood back to the heart.

Finally, in the last three chapters Harvey reviewed a grab-bag of medical, anatomical, and embryological evidence which, although such facts did not prove the circulation of the blood, were highly consistent with it. Indeed, he argued, many of his pieces of evidence were not understandable on any other grounds than an assumption of the circulation of the blood.

Such, in overview, was the argument in the book that William Harvey published in 1628. His logic aimed to be rigorous and convincing, and it proved so, demonstrating his theories by direct observation and innovative experiments. As a result, there is remarkably little that one can point to, even 375 years

later, that is factually "wrong." *De Motu Cordis* remains a marvelous example, not only of a statement of the epoch-making scientific discovery of the circulation of the blood, but of how an investigator should conduct experimental inquiries, and of how to construct a maximally persuasive argument.

Robert G. Frank Jr.

Robert G. Frank Jr. teaches the history of science and the history of medicine at the University of California, Los Angeles. His book, *Harvey and the Oxford Physiologists: Scientific Ideas and Social Interaction* (Berkeley: University of California Press, 1981) was awarded the William H. Welch Medal of the American Association for the History of Medicine in 1983.

De Motu Cordis Binding

The binding of Harvey's *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* is of modern chestnut brown goatskin over pasteboard measuring 7 1/4 x 5 7/8 inches (183 x 150 mm). The front and back boards have two square panels composed of gilt triple rules: the outer panel extends to the edges of the boards and has small decorations at the corners; the inner panel has large arabesque decorations at the corners. The spine is flat and undecorated with titling running from tail to head. The boards have small Yapp edges on the fore-edge.

Click here to see binding

Collation 4^0: A-I^4 [$3 signed], 36 leaves, pp. [1-2] 3-72 [=72].

Contents: $A1^a$: title page. $A1^b$: blank. $A2^{a-b}$: dedication to Carolo Magnae. $A3^a$-$B1^a$: dedication to D. Argent. $B1^b$-$C2^a$: preface. $C2^b$-$I4^b$: text. Insert: two plates facing $I4^b$: Plate 1, Figura 1 & 2; Plate 2, Figura 3 & 4.

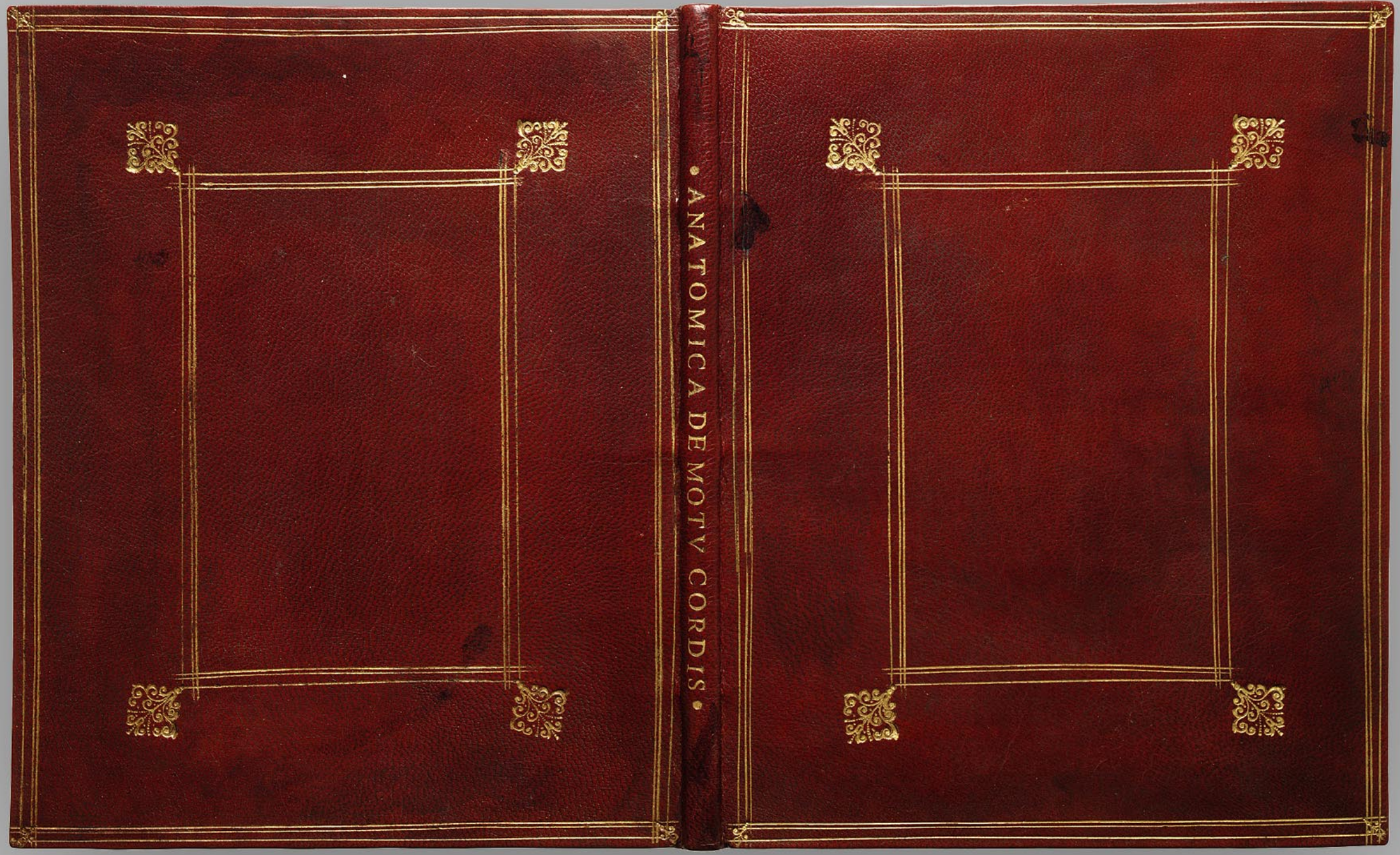
Provenance

Only fifty-eight copies of the first edition of Harvey's *De Motu Cordis* are recorded in the latest census, included in the third and final edition of Geoffrey Keynes' *Bibliography of the Writings of Dr. William Harvey, 1578-1657* (as revised by Gweneth Whitteridge and Christine English in 1989). The copy reproduced here, of Russian provenance, is not included among Keynes' and Whitteridge and English's count. It seems likely that further copies from Eastern European sources will be reported in years to come, but *De Motu Cordis* will always remain a rare book.

This particular copy was sold at Christie's in London on June 28, 1995 as lot 253. At that time, it was bound in late nineteenth-century cloth-backed boards (an unworthy binding for a book of this stature) and bore the lithographic book label of the Grand Duke Nikolai Mikhailovich (1859-1919), a grandson of the Tsar Nicholas I. Wealthy aristocrats tend to own costly books whether they read them or not, but in this case it is not improbable that the Grand Duke may have taken a personal interest in the contents of *De Motu Cordis*. He was himself not only something of a historian but something of a scientist, publishing several books in both disciplines and holding high office in the Russian societies devoted to each. In history, as it often happens with scholars in his position, the Grand Duke favored the study of genealogy and the biography of the ruling class; in his chosen science – entomology – he pursued only the most glamorous insects, the most impressive when pinned: the lepidoptera. His *Mémoires sur les Lepidoptères* appeared in nine volumes between 1884 and 1901, under the name "N. M. Romanoff."

Bookplate of Nikolai Mikhailovich

Nikolai Mikhailovich was murdered in St. Petersburg in 1919, and along with the rest of the imperial family, more or less vanished from Soviet history. His bookplate and humble binding are now gone as well, for the volume has since been very slightly trimmed (disguising the fact that leaf E1 has been supplied from another, slightly shorter copy) and rebound in chestnut brown morocco in expert facsimile of a period binding. The marbled endpapers are perhaps more in the taste of the early eighteenth century than the early seventeenth century, and the lettering on the spine is a trifle too precise, but otherwise the imitation is perfect.



William Harvey. *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* Frankfurt, 1628. THE WARNOCK LIBRARY

EXERCITATIO

ANATOMICA DE MOTV CORDIS ET SANGVINIS IN ANIMALIBVS,

GVILIELMI HARVEI ANGLI,
Medici Regii, & Professoris Anatomiæ in Collegio Medicorum Londinensi.

FRANCOFVRTI,
Sumptibus GVILIELMI FITZERI.
ANNO M. DC. XXVIII.